GENERAL NOTES.—SKETCH ON THE GEOLOGY OF YORK COUNTY, PENNSYLVANIA.

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The conditions which make York county soil productive, the study of its geology interesting, and that geology itself varied, are due to effects of movement in early geological time, which, compared with those which have shaped our continent, are so small that they can hardly be represented upon a geological map of the United States of ordinary size. Yet, in a rough and general way, York county is a partial imitation, on a very small scale, of the United States, inasmuch as, like that part of the American continent, it consists of a belt of Archæan rocks in the north-west; of another in the south-east; and that its intermediate portions are made up of newer formations containing fossils. Cavities in the limestone containing lignite and fossil plants, the latter resembling that of the present day, are not rare. These and possibly a marl in Carroll township near Dillsburg, which, however, has yielded no fossils, represent the latest geological period; and thus it may be said that of the five great divisions of the rocks of our planet: viz, the "original" (?) or Archæan; the "old life" or Palæozoic; the "middle life" or Mesozoic; the "new life" or *Cainozoic (including under this head the Quaternary and Recent), and the Eruptive or igneous, each has a representative (or several of them) within the confines of the county. If it were of interest or profit, the analogy might be pushed a little farther to include the occurrence of the igneous rocks in the north-west; the broad belt of Mesozoic strata which abuts upon the Archæan (but, in the case of the continent, also upon numerous masses of new rocks which are scattered over a great part of their junction); the contact of the Palæozoic (Siluric in both cases) on the south-east border of the Mesozoic and the contact on the south-east of the latter formation with the Archæan. The last feature of the United States' geology, which fails in the case of York county, is the border line of New Life or Cainozoic rocks to the south-east of all the above formations; and even this might be supplied if the limits of the county were pushed a comparatively short distance across Mason and Dixon's line, and into the State of Maryland. But enough has been made of this fancy, which is only introduced in order to fix more securely upon the memory the fact that, geologically speaking, York county may be considered to be a part of a great accidented plain of which the general trend is east of north and west of south. Its valleys, or portions of them, have successively formed the ocean bottoms of four or five different geological periods, probably extending from first to last over many millions of years.

To Rogers' names of "Primal" (or the beginning); "Auroral" (or

* Written frequently Cenozoic.

the *dawn* of life); "Matinal" (or the morning. Same metaphor); "Surgent" (or rising), &c., to the lower divisions of the Palæozoic; and "Cadent" (or falling); "Umbral" (or darkening); "Vespertine" (or evening), &c., to the later divisions of the Palæozoic, the insurmountable objection is made that they do not describe any general state of facts. Thus it might be asked: Of what are these rocks the beginning, dawn, evening? Evidently of the second only of the four arbitrary and artificial divisions by age which geologists have constructed for their temporary convenience. The plan adopted by the New York geologists of giving a name to each formation, which should either recall the locality where it was characteristically displayed, such as the "Potsdam sandstone;" or describe it lithologically, as the "Calciferous sandrock," the "Marcellus shales," the "Oneida conglomerate," &c., would be a good one for provisional use, were it not that in addition to the geographical designation, a lithological definition is added, which, because restricted in the area to which it is applicable, is as often inaccurate as the *time* description of Rogers. Thus the "Potsdam sandstone" is a "Hellam Township quartzite," in York county, and Prof. Fontaine, of Virginia, thinks it represented by a peculiar schist containing quartz fragments in Virginia; and some persons are sure that it occurs in other places as a gneiss. The "Calciferous sandrock" of New York is the same formation which makes up the major part of the broad and fertile limestone valleys of Lancaster, York, Cumberland and Franklin counties, &c., where it is not a sandrock at all.

As there are various objections to every system yet proposed, I have adopted here that recommended by the International Congress of Geologists at its Berlin session.

The Archæan (or beginning) in this classification comprises those rocks, usually crystalline in structure, but of very varied and divergent character, in or below which the very earliest known forms of life occur—and those very sparingly—in York county. This series comprises all the rocks which are geologically inferior to the Hellam Township quartzite.

The Palæozoic (or "old life") includes all the rocks from and including the Hellam quartzite to the New Red sandstone, and is made up of the quartzite, hydro-mica schists, and their included iron ores, the great blue and buff limestone on which the city of York is built, together with that of Lower Windsor township; that near New Holland, in Manchester township; around Newmarket in northern Fairfax township; and north of Dillsburg in northern Carroll township.

The Mesozoic (or "middle life") rocks are the reddish-brown sandstones and shales (and perhaps the igneous rocks penetrating them) which cover almost the entire north-western part of the county. If the fancy might be indulged of likening the outline of the county to that of the lower part of a horse's leg, this formation would constitute the fetlock joint and all that portion immediately above the hoof proper.

The Cainozoic (or "new life") includes all those rocks of which the

origin is of later date than the last mentioned, but it is generally used for those before the date of any historical evidences of the appearance of man on the planet. It is not known to me that there is a representative of this age present: that marked "marl" in the geological map being introduced without the evidence of fossils so far as I know and with considerable doubt.

The Quaternary and *Recent* deposits comprise those deposits which have been made from the earliest appearance of man on the planet down to the present time, including of course those of origin so late that they might have been historical. Such are the marks of the denudation which has shaped the meadows and hills as they are at present; the moulding of the ravines and deepening of the stream-beds; the distribution along the latter of gravels, &c; and finally (for the sake of saving one more division of time, which would otherwise lie wholly within this one, and at best remain very uncertain as to exact date) the works of man's hand, which are discoverable in the arrow-heads and sculptures not infrequently observed along the lower course of the noble river which forms York's north-eastern boundary.

One word more is necessary as to the subdivision of the rocks of these different geological ages before their occurrence in York county becomes our theme.

It has been said that if the average thickness of all the strata which have been yet recognized as distinct in the State of Pennsylvania were laid one upon the other, the height of the pile would reach something like forty thousand feet. But this is made up almost without taking into account other than the Palæozoic rocks. If the ordinary methods of calculation were pursued in estimating the thickness of the Mesozoic or New Red sandstone and shale alone which crosses York county, three miles and a half would be added to this column.* No very great thickness of Tertiary or Cainozoic rocks is to be found in Pennsylvania, but if, instead of counting upwards, or from the most recent of the Eozoic series, we were able to count downwards to its lowest member; or to the earliest existing rocks of the globe, it is probable that a thickness of this series alone greater than all of those that we now know put together would be established. That the exposures of rock in York county will not justify the belief that any considerable fraction of this Archæan series can be reached by boring, the following list of its divisions, accepted by many geologists, will sufficiently show. They are given in descending order, the lowest being the earliest known, and the first named the most recent:

VI. Keweenian.†	III. Huronian.
V. Taconian.	II. Norian.
IV. Mont Alban.	I. Laurentian.

*There are, however, good reasons for rejecting such an estimate.

†See volume E, p. 241, Publications of the 2d Geological Survey of Pennsylvania, by Dr. T. Sterry Hunt.

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The Archæan Rocks of York County.*

Crystalline Schists (a_2).

I have not seen in York county any rocks which I considered to be of Laurentian age. If there be any, they are to be sought in the portion of the South mountain, which is included in parts of Carroll and Franklin townships, but it is very improbable that any will be found there. The same may be said of the Norian, which is simply another name for what was once called "Upper Laurentian." There remain then only the Huronian, the Mont Alban and the Taconian, for the Keweenian is not known in this part of the United States. The lowest member of the Archæan series, which has been recognized in York county is the Huronian, and if I be not in error, the rocks of this age form the greater part, if not all, of its lower strata. On the accompanying geological map it is colored a pink of medium tint, and lettered "a_2," as well as all that previously referred to in Carroll and Franklin townships forming the South mountain.

Crossing the Susquehanna somewhat obliquely a broad flat arch of these rocks becomes evident in plotting the observations on section lines along either the right or left bank of the river.†

The perpendicular thickness of the Huronian rocks which constitute the visible parts of this arch has been calculated by me to amount to fourteen thousand four hundred feet, or 2.7 miles (or 4.3 kilometers), measuring from the lowest rocks exposed a short distance above McCall's Ferry to the base of the Peach-Bottom slates. This arch (or anticlinal) is a very important feature in the geology of this part of the State; for it is not improbable that it is the leading element in the structure of a broad belt of rocks extending from a point at least north of the Schuylkill river (and not improbably even within the New England States) to and into the State of Alabama.

But whether this carefully considered hypothesis be true or not, there is not the slightest reason for doubting that the rocks of this part of the county form the floor on which all the others in the county were laid down. Another fact in relation to this flat arch or anticlinal remains to be considered, viz: the line along its crown (or along the top of the arch) appears not to have been an horizontal line after the last great earth-crust movements, of which we can find evidence in this part of the continent, had been completed; the *axis* of this arch appears to have sloped upwards, from the west of south to the east of north; and to say that this axis rises towards the north-east, is to say that, judged from our present surface, the lower (and consequently older) beds of this arch rise nearer to that surface, the farther one follows this direction of north-east; and of course these same rocks sink lower beneath the surface

*See Note 7 at the end.

†See these sections by the author in atlas accompanying volume CCC, 2d Geological Survey of Pennsylvania.

the farther one follows the direction of the arch to the south-west. I have elsewhere given reasons for the hypothesis that this anticlinal joins and continues the anticlinal of the Buck Ridge * near Conshohocken, a few miles north-west of Philadelphia, on the Schuylkill river, traversing Lancaster and Chester counties, a little south of the Chester valley. But at Conshohocken, the anticlinal is represented by Laurentian gneiss, while in Lancaster and York counties, the Huronian schists, which have been torn off by atmospheric denudation at the former locality, still remain ; and still farther to the south-west it is not unlikely that even more recent sheathings may be found, unless the axis be broken or bent, and rise also in this direction. The main fact, which it is my purpose to emphasize here, is that the same structure of arch evidently affects an enormous thickness of beds ; in all probability is traced in the flexed rock masses of at least two entirely different geological periods, and may possibly be discovered in those of yet others outside of the limits of the field which it is my purpose to describe.

A somewhat arbitrary division has been made by the writer between the rocks of the Huronian and those of the next following age. The line which constitutes this division may be seen passing through the southern part of Lower Windsor, the middle of Windsor, the eastern part of Springfield, including Codorus, and reaching the Maryland line a short distance east of the boundary dividing Manheim from West Manheim township. This line does not profess to be, and in all probability is not an accurate line of demarcation between the two formations. It was adopted as an approximate dividing line between two regions which exhibit lithological characteristics diverging from each other in a degree proportional to the distance on either side of it. The same is true of the line which separates these lower rocks from the triangular area in the extreme south-eastern corner of the county, in which are found the famous Peach-Bottom roofing slates. These two lines, which are in the average parallel to each other, are approximate boundaries only between the two regions, and that filled by the rocks of the McCall's Ferry or Tocquan Creek anticlinal. The rocks of the latter belt are strongly marked crystallized rocks,† *i. e.*, their structure is coarse, and the minerals which compose them are large and well crystallized, especially along the central parts of the belt. The rocks of the two bordering regions just mentioned are more crystalline, *i. e.*, crystallized imperfectly or in much smaller masses, besides having other differences in kind. For example, the arch-belt (if I may be permitted to express it so), contains larger amounts and larger specimens of Muscovite, and more potash micas generally. The rocks are lighter, and not infrequently enough feldspar is found to give them a decidedly gneissic character; and the more so in general terms, the farther one gets away

*See "Thèses presentées a la Faculté des Sciences de Lille. Université de France," &c., 1882, and "History of Lancaster County," &c., Phila., Everst & Peck Publ., 1883, p. 3.

†See note at the end.

from the bordering regions. The rocks in these latter regions, on the other hand, are more and more magnesian, darker in color (usually greenish or yellowish-green) and softer. They contain large quantities of chloritic minerals, and are remarkable for the great number of white quartz dykes which intersect them.

These "arch-rocks" are very generally destitute of valuable minerals, so far as they have been explored in York county, except on the fringe of the South mountain, where they are in close proximity to a series of iron ore deposits similar to and in fact continuous with those known as the ores of the "Great," or "Cumberland Valley." But though this juxtaposition would tempt one to connect these ores with the rocks just spoken of, and though it is conceded that rocks of this age do often carry iron ores, the strong probability is that the proximity is "accidental," that is to say, that the ores occur at the foot of the mountain, because having been originally imbedded (as constituents of minerals) in the rocks which covered these slopes during the degradation and destruction of these latter they have been disintegrated, carried away from their original place (sometimes not far off), and segregated in the soft and unctuous clays to which these loose beds have been reduced. But it is not improbable that some of these ores may have owed their origin to the same kind of alteration taking place within the mass of the Huronian rocks themselves. So that wherever the loose débris of higher formations (and notably of the Hellam quartzite (Potsdam sandstone), which everywhere abounds on the slope in boulders and blocks) will permit the undoubted Huronian to appear near one of these great iron mines, it is likely to be found that a part of the wealth of the latter consists in a somewhat peculiar ore unlike the rest, which can be traced to its first resting place within the bosom of the Huronian rocks.

The belt of rocks which represents the Archæan in York county, lies, as it may be said approximately, between two lines, one following Muddy creek from its mouth in the Susquehanna to its right-angled bend, and thence through Bryantsville to Constitution ; and the other commencing opposite Turkey hill (in Lancaster county), and passing north-west of Windsor post-office, south-east of Dallastown, and nearly through Glen Rock post-office. The portion of the South mountain above referred to as belonging to the same age is small in area within the county limits, and occurring at one end of the chain of crystallophyllites where they appear to sink beneath the newer limestones and shales ; its slopes are gentler ; it has been subjected to greater erosion, and is covered for the most part with the débris of more recent formations. This belt, thus defined, contains no minerals which are yet mined (if we except the iron ores from the category), but the soil formed by the chemical and mechanical action of the atmosphere on its rocks is next in fertility to that of the limestone belt itself. The rocks of the Archæan belt, thus defined, are intersected by but few igneous dykes or trap, and this fact, taken in connection with the remarkable prevalence of such dykes in the north-western part of the county,

and their frequency throughout the middle belt of limestone and schists, would lead one to conclude either that the seats of the igneous action resided within the beds of the newer rocks, or that the superposition of the latter in some way favored the development of the Plutonic forces which have forced molten rock for miles through narrow crevices and cracks in the envelope of the globe. Perhaps the explanation may be found in the supposition that the number of such dykes would depend upon the number of fractures in the earth's crust, and that this number would increase with the growing weight due to thickening sediments deposited by water. However this may be (and it does not explain all of the facts connected with the new red sandstone), the only points where have observed trap penetrating and terminating in the rocks of this belt are: First, in a small exposure north of York Furnace on the Susquehanna, and second, a short distance east of Black Rock post-office.

The Belt of Azoic Schists or Phyllites (a_3).

I have preferred to describe this belt under a separate heading, because there are difficulties connected with its assignment, either to that part of the Archæan rocks just considered, or to the Palæozoic which will next be described. These difficulties arise in great part from the lack of outcrops of "rock in place." The decomposition which has attacked this intermediate belt has destroyed the identity of the individual beds and strewn the surface with its products, which are mingled with the remains of rocks of much later date. This is not surprising if we may assume that this belt formed the upper and later portions of the great Archæan series, for we have abundant proof that in contrast to the stability and repose of the broad flat arch to the south-east, this new region was the hinge on which the first of a number of severe plications of the strata were operated. This bending and twisting unquestionably crumbled the rocks and left loose material which was easily moulded by the waters of the ocean, which then or subsequently covered it, to forms which more or less resembled those which had originally characterized it. But after its consolidation with the next succeeding formation, and after an unknown amount of erosion had laid bare their contact line, both were together similarly treated, so that in the contorted state in which it was left it exhibits some features which recall the Middle Archæan, and others which remind one of the Lower Palæozoic of the county. Its precise boundaries being difficult to ascertain on the ground, cannot be given with precision in the text. It will suffice to say that, beginning on the Susquehanna river, a short distance south of the southern outcrop of the Prospect limestone, one part of it occupies all the region lying between the north-western boundary of the Archæan already given and the southern and eastern limits of the Hellam quartzite shortly to be described. It is traversed through part of its extent by two large trap dykes, and contains numerous deposits of iron ore which I am disposed to ascribe to segregation from iron minerals in other formations. Some limestone occurs interbedded with these rocks

(as at Glen Rock), which may be safely assumed to be of earlier date than the important York limestone, whether or not it be (as seems not improbable) a part of the regular Huronian series.

The most extensive iron ore banks noted in or on the border of this intermediate belt are the Brillhart and Feigley banks marked Nos. 11 and 12 on the map.

The Peach-Bottom district, including the roofing slates lying to the south of the flat arch, was described by me in volume CCC, Second Geological Survey of Pennsylvania, in 1877, where I showed that its position in the series was doubtful, and that these rocks might be interpreted to represent the Upper Archæan (a_3) (below the Potsdam); or the schists immediately above the Potsdam (s_1); or (by supposing a fault), a formation still higher—the "Matinal" of Rogers. Since then fossil algæ were furnished to Prof. James Hall from the quarries, but he was unable to determine the age of the rocks from them with greater precision, than to refer them to the second or third of these horizons, with a preference to the second.* Photographs of the quarries and of the manner of working them will be found in volume CCC, Second Geological Survey of Pennsylvania.†

The Palæozoic Rocks.

Cambric (Hellam Quartzite, Potsdam Sandstone). (cb)

Prof. H. D. Rogers, in the First Geological Survey of Pennsylvania, marked out and described the members of the different formations represented in the State. This formation, which we may consider the base of the Palæozoic, was considered by him to consist of three parts: a lower series of "talcose" slates, a middle white sandstone, and an upper series of talcose slates. It will be easily understood, by what has just been said, to what extent the view here offered differs from that of our great pioneer geologist. These "lower talcose slates," in all probability, are identical with the Azoic schists (or phyllites) just described, and, therefore, their position relatively to the beds beneath them and above them is the same, whether they be considered Upper Archæan or Lower Palæozoic. There are no good exposures of the Hellam quartzite with the slate below it at any place in York county which I recall. On the flank of the South mountain, the quartzite is very much rent and crushed into fragments, while of the small patch on the map about two miles west of Case's ore bank (No. 8 on the map) no accurate dip was recorded. The Hellam quartzite, of which a part composes the "Chikis mountain," exhibits, indeed, in its numerous foldings the rock, called by Rogers, "talcose slate," between its two principal beds of quartzite, but not appreciably lower than the latter. We are forced to look to other parts of the country for a clearer knowledge of the relation to each other of this quartzite, and the schists on which it rests. We find abundant instances

*See Peach-Bottom slates of S. E. York and S. Lancaster counties, Proc. Am. Inst. of Min. Engrs. Troy meeting, 1883.

†See note No. 2 at the end.

of this contact in Chester county north of the valley of that name, and in all of them the quartzite lies "uncomformably" (*i. e.*, with changed dip) upon the schists. The latter, it is true, are somewhat different in minor characteristics from those of which it is here the question, but so also is the quartzite. Yet we have the best reasons for believing that each is of contemporary origin with its analogue in York county; and indeed, the differences, which would not be considered at all important by any but a critical geologist, are what we might expect when we remember that these rocks are sediments laid down at the bottom of successive seas, and that their characters depended upon the kind of material which different streams draining different parts of the country brought down to be strewn out at different localities during different epochs.*

It will be explained before long that the physical break between the Archæan schists and the limestone series is rendered highly probable by the observations in York county, but that between the flat arch belt and the Hellam township quartzite must rest upon the direct evidence obtained in other counties, unless here also we may apply the indirect method mentioned above, and conclude that inasmuch as the Hellam quartzite contains one important fossil (*Scolithus linearis*) and the Archæan schists contain none that have yet been discovered in York county, this fact alone entitles them to be considered different formations.

The Hellam or Chikis quartzite is a hard quartzose rock, of which the general color is white or gray, tinted by some other color, usually pink, brown or blue, depending upon the minerals with which it has been associated. It is almost always crystalline, and in disturbed regions like this is most frequently found in broken fragments rather than in continuous beds. This is probably owing to its brittleness, which prevented it from yielding gradually to the strain which has folded and tilted the other rocks of the county. These strains have twisted, broken and crumbled it, but on account of its great hardness and its resistance to the chemical action of the atmosphere, it is the least altered or decomposed of all the rocks to be considered here, and almost always indicates its presence by a hill, whatever be the position of its strata.†

It is not necessary to specify the localities within the county where this quartzite occurs, because they are indicated by brown on the accompanying geological map; still less is it desirable to discuss here all the possibilities of structure which these scattered outcrops suggest. It is important, however, before leaving the floor of the Palæozoic column, to say that eleven years of experience in the field have caused me to doubt the cor-

* Let any one observe the great differences between the characters of the sand beach of our own Atlantic coast within short distances. See on this subject Delesse's important contribution entitled "Géologie du fond des mers," and the writer's notice of the same in the Proc. Am. Philos. Soc.

† Of course the reason of this is that the erosion, which has torn off hundreds and perhaps thousands of feet of the other measures, has not been able to reduce it to the same extent, and it remains, consequently, as an elevation, or chain of hills.

rectness of ascribing to this formation the iron ores which are found in the schists immediately above the quartzite.*

The Grubb ore bank (No. 111 of the map) is the only one which lies wholly within the area of the Hellam quartzite as given on the map, but a reference to the description of this bank (Vol. C, p. 64, 2d G. S. of P.) leads to the belief that the larger part of the ore lies in a small remnant of the bottom schists of the next higher formation, which has escaped the erosion that cut off the higher layers of that formation. Part of it, however, answers to the description of an iron ore which may really belong to the quartzite and which has been noticed in the rocks forming the outer casing of the South mountain.†

Siluric. (s)

The York Limestone and Schists (*Auroral* of Rogers, in part the *Calciferous Sand rock* of the New York Survey). This important member of the Palæozoic series in York county consists of at least two, and perhaps three, distinct kinds of rocks, and inasmuch as the kind that occurs at the bottom (which resembles strongly that which occurs among the limestone beds themselves, and also above them) has already been mentioned several times by anticipation, it will be advisable to consider it first.

Hydro-mica Schists. (s_1)

It was previously stated that Rogers, and following him, almost all other writers on geology up to the commencement of the Second Geological Survey of Pennsylvania, had given the name of "talcose slates" to a group of rocks which he connected in epoch with the quartzite. The word talcose was applied to them because from their softness and greasy feel it was assumed that they were largely composed of "talc;" but subsequent investigations of these rocks in the chemical laboratory have shown that they contain little or no magnesia, and that they derive their peculiar characters from large amounts of a group of micas containing potash or soda and water. Prof. James D. Dana conceived the happy thought of naming the group the "Hydro-micas" (or water-containing micas), and naturally the rock which is mainly composed of them is called Hydro-mica schist.

These hydro-mica, or nacreous schists, are not of uniform appearance. Sometimes, and especially in the beds that underlie the limestone, they are firmly compacted together, making hard rock masses and high hills, as at many places along the Susquehanna, from Wrightsville to Cabin Branch run, and elsewhere in the county. Sometimes they are so much disintegrated as to form dust, which on close view is seen to be mainly

*Of course, if the Potsdam have an upper member consisting of schists, the above assignment is correct; but I know of no instance in which the opposite supposition is not equally supported by the facts. It is also to be noted that the limestone and iron-ore bearing schists are more frequently found together without the quartzite, than the quartzite and schists without the limestone.

†Cottrell, Benson's and Smyser's mines (Nos. 11 and 112) are on the border line between the quartzite and limestone.

made up of little glinting particles. In the former case the beds are very often strewn with pyrite. Again, in place of these crystals of iron—and occasionally copper—sulphide, are beautiful casts or moulds of the shape of a cube, more or less filled with a dark brown iron rust obtained from the decomposition of the original crystals. These little crystals have been of no small importance to the prosperity of York county, for there is good reason for believing that by far the largest part of its iron ores have been derived from their oxidation, transportation by water and final deposition in the clays formed from the grinding up of the rocks which originally contained them.*

These argillites, or limestone schists, as I have sometimes called them, in all probability hold all the important iron ore† mines of the county, outside of the formation of red sandstone and shales. It is true that sometimes the iron ore banks appear to be far from the area colored as limestone, and sometimes directly within the boundaries of that area, but in neither case is it under conditions that forbid the belief that they are in the veritable hydro-mica schists, even if the latter may have been reduced by the weather to soft unctuous and variegated clays. It is not assuming too much, therefore, to call this portion of York county rocks the real iron-bearing region. The edges of the rock appear in the right bank of the Susquehanna river, where that river has cut through them, and one would select the part just above Wrightsville to ascertain whether these schists were unconformable upon the quartzite; but the following records of the dip, or inclination of the two rock series taken from section 1 of my report on the county,‡ will show that both formations are so flexed or twisted, that no certainty can be obtained there. First, there are two dips in the Quartzite of South—50°, and almost at the contact with the schists S. 20°, E.—45°. Next there are three dips in the schists which are respectively S.—45°, S. 10°, E.—50°, S.—10°, E.—10°. Still, there is every probability that in fact the dips of the two differ, both in direction and amount, while there are no such indications for the dips of the schists and of the limestone proper at this place.§ These schists are colored dark-green in the accompanying map.

The York Limestone with Argillites.—One of the best opportunities of measuring the thickness of this limestone is afforded by the section referred to along the Susquehanna from a little run half a mile above the Columbia bridge to Creitz's creek. This is evidently a trough with the axis close to the bridge, and measures 2800 feet of limestone and included schists. If the schists between the quartzite and the limestone be included, it would add some 1600 feet to this, making the limestone

* See Volume C, p. 137, 2d G. S. of Pa., by the author.

† See Note 3, at the end.

‡ Vol. C, p. 78.

§ In the section above referred to it is probable that a further study would enable me to abandon the hypothesis of non-conformability at *g*, *i*, *k* and *o*, which I considered necessary eleven years ago.

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and the schists below it to the quartzite 4400 feet thick. The same beds measured by me in Lancaster county only amounted to 3400 feet. These beds, therefore, thicken 1000 feet in the twelve miles which intervene between this section and the city of Lancaster, and of this thickening 400 feet belong to the schists below the limestone and 600 feet to the limestone itself and its included schists.* The limestone, of which numerous analyses will be found in Reports C, CC, CCC, M and MM, is dolomitic, that is to say, it is a carbonate of lime, containing varying amounts of carbonate of magnesia. There is also some ground for believing that two kinds of limestone are represented, each having its own peculiarities of physical structure. It was noticed in many cases that two kinds of limestone were often exposed in the same quarry, and that they usually showed slight variations of dip. One, which was apparently the elder, was of a buff or grayish color, and less marked stratification; the other blue, with white streaks and spots of lighter colored limestone (often calcite). One case was recorded where, in a contact between the two, pebbles of the buff were found in the blue. There seems no doubt that the great mass of limestone now under consideration was formed subsequently to the quartzite, and at about the epoch of the Calciferous Sand-rock of New York and before the Trenton, or in other words in the Canadian epoch of Dana. But no fossils were found in the county to settle the question. The portions of the beds connecting the limestone near New Market with that of York (a connection which doubtless exists), is covered up by the beds of the Mesozoic. Those which once connected that of Wrightsville with that near Prospect has been washed away in the general planing down of the surface by erosion. The limestone is indicated in the map by white line blocks through the dark green.

The Mesozoic Rocks in York County.

None of the numerous members of Mesozoic rocks is known to be represented but the groups of sandstones and shales known as the "New Red Sandstone," and sometimes the "Triassic Sandstone."

There are many puzzling questions which arise from the study of these rocks, not the least of which is their thickness. If one assumes them to lie naturally without distortion, layer upon layer, in York and Adams counties, their perpendicular thickness in this region will be not less than sixteen thousand four hundred feet.† The lower bed of this formation,

*See Note 4, at the end.

†See Volume CC, 2d G. S. of Pennsylvania, p. 303, by the author. See also by the same "The American New Red Sandstone." Trans. A. I. M. E.; "The Mesozoic formation in Virginia," by C. J. Heinrich; Trans. A. I. M. E., Feb., 1878; Notes on the Mesozoic of Virginia, by Prof. William M. Fontaine, Am. J. of Sc., January, 1879; and "Some Mesozoic ores," Proceedings American Philosophical Society, April 20, 1877, by the writer. In the article cited second, and in a review of the others in the *American Naturalist* for May, 1879, I have shown that by calculating the thickness of Prof. H. D. Rogers' Yardleyville section of this formation (First Geological Survey of Pennsylvania) by the ordinary method, the thickness of beds would appear to be 51,500 feet, or nine and three-quarter miles.

which forms its eastern boundary, is very generally a conglomerate of the older limestone pebbles, forming Mesozoic rocks. This can be observed about two miles west of York, at Beeler's Cross roads (Vol. C., p. 92, Sec. 2a).

The upper bed seems to be also a conglomerate which forms its western boundary on the slope of the South mountain. Rogers was in doubt, whether the so-called "Potomac marble" was represented by the upper or lower of these (see Report CC., p. 265). Borings with the diamond drill by Mr. Heinrich, recorded in the paper above mentioned, show that no such thickness exists in point of fact as one might conclude from the appearance of the beds, and the probability is that the actual thickness there is not above fifteen hundred feet. No such borings have been made in York county, but the probability is that this thickness is not very greatly exceeded. But these measures in York county are chiefly interesting on account, 1st of their fossils; 2d of their iron ores; and 3d of their coal. From the former Prof. E. D. Cope was able to assign the beds containing them to the middle and upper divisions of the Triassic. The coal which is found about three-quarters of a mile north of Liverpool on I. Spahn's farm, and elsewhere, represents the extensive deposits known as the Richmond Coal fields, which have been wrought for a century in Virginia to advantage, and are so still. Although its analysis indicates it to be a good bituminous coal (see CCC, p. 259*), yet it has never been found in Pennsylvania in paying quantities.

Copper, and other valuable metals have been similarly observed in this formation, though in disappointing quantity, in this county, though they have supplied furnaces in other parts of this State and in other States. The richest deposits of these metals are usually found near the borders of the formation. For the following summary of the Triassic fossils as yet determined in Pennsylvania I am indebted to the kindness of Prof. Cope.

The vertebrate fossils from the Triassic beds of Pennsylvania have been obtained principally from two localities by Mr. C. M. Wheatley. The longest known is the tunnel of the Reading railroad at Phœnixville; the other is in York county.† The species represented belong to the Fishes, Batrachia and Reptilia, as follows:

Fishes.

Turseodus acutus Leidy.....Phœnixville.

Batrachia.

Eupelor durus Cope.....Phœnixville.

Reptilia.

Belodon priscus Leidy.....York Co., Phœnixville.
" *carolinensis* Emmons.....York Co., Phœnixville.
" *lepturus* Cope.....Phœnixville.

*See Note 5 at the end.

† About two miles north of west of Emilysville and one and a half miles from the south-eastern border of the Mesozoic.—P. F.

Palæosaurus fraserianus Cope.....York Co.
Suchoprion cyphodon Cope.....York Co.
" *aulacodus* Cope.....York Co.
Clepsysaurus pennsylvanicus Lea.....Phœnixville.
" *veatleianus* Cope.....York Co.
Palæoctonus appalachianus Cope.....York Co.
Thecodontosaurus gibbidens Cope.....York Co.

Total, twelve species, most of which are described in the Proceedings of the American Philosophical Society for 1877.

Of the above, the genera Belodon, Palæosaurus and Thecodontosaurus are typical Triassic forms. The first and last named are the most clearly determined. Belodon is characteristic of the Keuper in Europe. As the species found in North Carolina and in New Mexico (*B. scolopax* and *B. buceros* Cope) are characteristic members of the genus, I have identified their horizons with the Keuper. The specimens from Pennsylvania are not so perfect as from the other localities, but are not separable from them. Thecodontosaurus belongs to the base of the Keuper (Etheridge).

No vertebrate remains indicating the existence of the Muschelkalk have yet been found in North America.—*E. D. Cope.*

Iron Ores. What has been said of the copper and other metals, may here be said of the iron ores. Although an immense amount of iron must have been consumed in providing these beds with their characteristic red color, and in fact large quantities of thin oxide scales are to be observed almost everywhere between the strata; the only localities where iron ores appear to have been found in any abundance or permanence are: 1st, those near the margins of the New Red Sandstone, when it overlies another formation containing iron ore; and 2d, in the neighborhood of the trap dykes, which contain over 11 per cent of oxide of iron.* In the former case, it is extremely probable that the deposits of the older beds (as on the flank of South mountain) have been torn up by the agitated waters which laid down the Triassic rocks, and redistributed as part of the latter. In the other case it is very probable that after the decay of the exposed portions of the Trap, part of their iron oxide contents was concentrated by natural water-flow, and carried into the cavities and seams of the porous Mesozoic rocks. The Traps, probably, not only supplied the original material for these ore beds, but in addition protected them from being washed away, and new outbursts of molten rock very likely gave them their altered appearance and magnetic character.

The Trap. Though the trap cannot be said to be of the same age as the Triassic (since it cuts through the highest beds and therefore appeared clearly after the latest sedimentary bed of the Mesozoic), still there is no sense. The most interesting features of the York county trap are its appearance sometimes as dykes cutting through narrow clefts of the rocks, and sometimes as mesas, or "tables" covering large areas after having

*See Note 6 at the end.

been poured out from a comparatively small vent. One of these may be seen in Warrington and one in Monaghan townships. The chief constituents of this rock are pyroxene (or augite) and labradorite. Magnetic oxide of iron is always, and apatite is very generally present. The trap in Warrington is directly connected with the mass in and to the east of Gettysburg, and is identical in composition with the so-called "Gettysburg Granite."* The Triassic is represented by a medium tint of violet on the map.

Cainozoic. Of these, including the Quaternary and Recent, the only representatives are the marl bed north of Dillsburg, (?) and the gravels, fluviatile deposits, and Indian sculptures on the banks and islands of the great river. Full descriptions and phototypes of these latter will be found in Vol. CCC, 2d Geol. Surv. of Pa.'s publications. Though in strict accordance with the determination of Prof. Cope, just given, it should be represented perhaps as t3, which is a violet of very light tint. No rocks answering to the description of the shell limestone or "Muschelkalk," which constitutes the middle Trias of Germany and France, have been found in Pennsylvania at least. Pending the establishment of a parallelism, I have adopted the plan suggested by the International Geological Congress, of coloring the entire area as if it were the middle member of the formation.†

Analyses of Ores, Rocks, Minerals, &c.

Note 1. An analysis of a mica schist with imbedded crystals from half a mile N. W. of Cully's station, Columbia and Port Deposit R. R., is added here for comparison with that of the Beach-Bottom slate which follows: (No. 1705 in Survey's catalogue of specimens, CCC, p. 271.)

	P. C.
Silica (SiO_2)	59.01
Titanic oxide (TiO_2)	1.34
Phosphoric oxide (P_2O_3)	(traces)
Alumina (Al_2O_3)	17.02
Iron sesqui-oxide (Fe_2O_3)	7.76
Ferrous oxide (FeO)	2.64
Manganous oxide (MnO)	0.96
Lime (CaO)	2.08
Magnesia (MgO)	0.07
Potash (K_2O)	2.63
Soda (Na_2O)	2.44
Ignition	4.42
Total	100.37

The rocks of which the above is an analysis correspond with those be-

*See Note 6 at the end.

†The above paper was rewritten from one intended for a history of York county. Some matters not entirely adapted to a paper in the Proceedings, but which were difficult to eliminate, still remain.—P. F.

tween Centreville and Castle Fin in York county, not far to the north-westward of the Peach-Bottom district.

Note 2. Peach-Bottom slates. Mr. Andrew S. McCreath gave the following report of a specimen of the Peach-Bottom slate taken from J. Humphrey & Co.'s quarry half a mile east of Delta, York county (p. 270, CCC).

	P. C.
Silicic oxide (SiO_2)	55.880
Titanic oxide (TiO_3)	1.270
Sulphuric oxide (SiO_3)	0.022
Alumina (Al_2O_3)	21.849
Ferrous oxide (FeO)	9.033
Manganous oxide (MnO)	0.586
Cobaltous oxide (CoO)	(trace)
Lime (CaO)	0.155
Magnesia (MgO)	1.495
Soda (Na_2O)	0.460
Potash (K_2O)	3.640
*Carbon (CO)	1.794
Water (H_2O)	3.385
Iron bisulphide (FeS_2)	0.051
Total	99.800

Note 3. The following analysis of two different kinds of ore from York county are given. The first is from the "Lower Auroral," or limestone schists. It is from Earley & Killinger's Mine two miles and one-half east by north of Littlestown. It was analyzed by Mr. McCreath (See C, p. 44).

	P. C.
Insoluble residue	12.320
Iron sesqui-oxide (Fe_2O_3)	67.000
Alumina (Al_2O_3)	0.950
Manganese sesqui-oxide (Mn_2O_3)	2.341
Phosphoric oxide (P_2O_5)	2.804
Sulphuric oxide (SO_3)	0.277
Lime (CaO)	1.680
Magnesia (MgO)	0.591
Water (H_2O)	11.890
Sum	99.853

In the above there were

Metallic Iron	46.900
" Manganese	0.815
Sulphur	0.110
Phosphorus	1.224

* Average of three determinations.

The following is the result of an analysis of the Mumper mine in the Mesozoic sandstone, one mile north-east of Dillsburg (C, p. 71.)

	P. C.
Ferrous oxide (FeO)	18.643
Ferric oxide (Fe_2O_3)	42.100
Pyrites (FeS_2)	4.093
Copper sulphide (CuS)	0.098
Cobalt sulphide (CoS)	0.766
Alumina (Al_2O_3)	2.417
Manganese sesqui-oxide (Mn_2O_3)	0.186
Lime (CaO)	6.132
Magnesia (MgO)	6.738
Potash and Soda	0.350
Phosphoric oxide (P_2O_5)	0.052
Sulphuric oxide (SO_3)	0.119
Carbonic acid (CO_2)	1.760
Water (H_2O)	1.080
Silica (SiO_2)	15.120
Sum	99.654
Metallic Iron	45.880
" Manganese	0.129
Magnetic Oxide of Iron	59.040
Ferric oxide	1.703
Sulphur	2.680
Phosphorus	0.023

Note 4. In MM, p. 344, Prof. Lesley gives some analyses which derive their interest from the fact that they are very numerous, and all from a comparatively small thickness in the Walton limestone quarry opposite Harrisburg. His paper in the Am. Phil. Soc. was presented Dec. 20, 1877, but the article just referred to is dated June 23, 1879. From analysis of 115 layers of the limestone exposed in the quarry, it appears

	P. C.
That the Carbonate of Lime constituted	80.662
" " " " Magnesia constituted	14.215
The insoluble residue constituted	4.715

Those proportions will give a better idea of the average constitution of the good merchantable York and Cumberland limestone than any number of scattered analyses. Prof. Lesley's attempt to ascertain a connection between a given horizon and a constant proportion of the carbonates of lime and magnesia to each other may have been suggested by some analyses which I had published previously with the same end in view (See CC, p. 307), in 1875.

The analyses made by myself are as follows :

No. 1. From the west branch of Creitz's creek, near Wrightsville.

No. 2. Upper bench of Pine Grove quarry.

No. 3. Lower " " " "

No. 4. White limestone 100 yards east of Beeler's Cross roads, 2 miles W. by N. of York.

No. 5. Was from Detweiler's quarry, N. W. of Wrightsville.

No. 6. " " " " S. of Wrightsville.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	Av.
Specific Gravity.	2.832	2.735	2.731	2.750	2.737	2.770	2.759
Insoluble Siliceous residue.	4.400	12.270	12.000	3.570	0.490	41.710	6.546
Alumina and Ferric oxide.	1.170	1.540	0.450	0.210	1.440	6.350	0.962
Carbonate of Lime ..	49.920	75.320	81.617	91.580	91.400	43.728	72.260
" of Magnesia.....	42.980	10.750	6.400	4.110	7.290	6.450	12.996
Sulphur.....	0.220	0.120	0.422	0.113	0.003	1.480	0.175
Sum.....	98.690	100.000	100.489	99.583	100.623	99.718	99.850

Note 5. Mr. A. S. McCreath's analysis of the coal referred to is as follows :

	P. C.
Volatile Organic Matter.....	18.482
Water.....	4.310
Fixed Carbon (by loss)	74.358
Sulphur	0.528
Ash	2.322
Sum.....	100.000

Rating this coal according to the system proposed by me in a paper in the Trans. Am. Inst. of Min. Eng. and subsequently published as part of report MM, the p. c. Carbon is to the p. c. Volatile Hydro-Carbon : : 80.1 : 19.9 and the "Fuel Ratio" would be 4 or within the range proposed for the bituminous coals : (5 to 0).

* No. 6 not counted in the average.

Note 6. The following is an analysis by Dr. Genth of the Trap (Dolerite) dyke, which crosses Beeler's farm two miles S. W. of York.

	P. C.
Silicic oxide	52.53
Phosphoric oxide	0.15
Titanic oxide	0.32
Alumina	14.35
Ferric oxide	5.93
Ferrous oxide	5.45
Manganous oxide	(trace)
Magnesia	7.99
Lime	10.27
Lithia	(faintest trace)
Soda	1.87
Potash	0.92
Copper	(trace)
Sulphur	0.08
Ignition	1.23
	101.04

By a mineralogical analysis of the results (C, p. 123 &) it appears that there are two molecules of labradorite and one of pyroxene which together essentially make up this rock.

Note 7. In a volume entitled "The Azoic system and its proposed subdivisons," by J. D. Whitney and M. E. Wadsworth, printed as a Bulletin of the Museum of Comparative Zoology at Harvard College in August, 1884, but which might well serve as a type of all that a scientific memoir ought not to be, the authors are pleased to dispose of the work on the Archæan rocks of this State as if it were entirely due to four persons representing all grades of experience, and various dates of activity from 1858 to 1880. The two elder and better known of the four are waved aside ostensibly because they are unreliable, in that they have modified their views, or did not feel justified in drawing sharp divisions on the map which were supported only by a high degree of probability. The younger and less generally known of these, though nowhere claiming to have solved the problem of sequence, are given a prominence which contrasts strangely with their own modest words. The mystery is, however, explained when we observe that the views of Prof. Rogers and Dr. Hunt do not accord with those of the authors of the volume, whereas Mr. Charles E. Hall leans towards the view that the mica schists of the Philadelphia group, the South Valley Hill rocks, &c., are well within, if not high up in the Palæozoic column; and Prof. Prime's merit in the eyes of these authors appears to be that he has differed with Dr. Hunt as to the age of the rocks in a certain mine in Berks county. The

many sections across the crystalline rocks of the South mountain and the hills and plains of Adams, York, Lancaster and Chester counties, with the evidence they contain of the pre-Palæozoic age of these rocks, which were published in Vols. C, CC and CCC, and the part of C_4 which Prof. Lesley has permitted to appear as it was written, are easier to ignore than to invalidate. It is not necessary to characterize the conduct of authors who, professing to discuss a subject in the interest of truth, and filling pages of their books, as well as parts of their index, with unjust imputations on the truthfulness and reliability of a geologist whose services to his science are recognized throughout the world, give an example of their own possession of this virtue by suppressing all that does not happen to coincide with their own peculiar views, but which (to compensate for this) forms by far the larger part of the literature on the subject. Profs. Whitney and Wadsworth quote Mr. C. E. Hall's paper in the Am. Phil. Soc.'s Proc. of 1880, but do not allude to the criticism of those views in the A. P. S.'s Proc. for Dec., 1882, nor even quote their author's summary of his maturer views printed in part of C_4. In the criticism of the views expressed in C_6 (which are virtually the same as those read before the A. P. S. and quoted at length) the author was supported at the time by Prof. Lesley (see "The Horizon of the South Valley Hill rocks in Pennsylvania"), and the structure on which he based his argument had received the endorsement of Profs. Gosselet and Barrois on the assumption of the facts of dip, &c., about which there was no dispute. The section at "Gulf Mills," on which Mr. Hall relied (C_6, p. 32) for his structure, is shown in the above paper, where it is independently given, to have been so drawn by Mr. Hall that every synclinal is in reality an anticlinal and vice versa, and this is confirmed by a later section published in the transactions of the A. A. A. S. of the Philadelphia meeting in 1884. Further information on this subject may be found in the "Théses presentées à la Faculté des Sciences de Lille," "Reply to a paper entitled Notes on the Geology of Chester county and vicinity" (Journal of the Franklin Institute, April, 1884) and "Review of C_4" (American Naturalist, October, 1883), by the writer.

Those who would discuss the Archæan of Southeastern Pennsylvania without reference to the lessons to be learned from the South mountain in Franklin, Cumberland, Adams and York counties, or the great flat Tocquan anticlinal of Southwestern Lancaster are incompetent to do so either from ignorance of the facts or from a disingenuous desire to suppress them.